PROGRESS TOWARD THE EXTERNAL POWERED HIGH GRADIENT DLA STRUCTURES

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Outline

- Introduction
- Report on the Latest Experiment @ SLAC
- New Designs To Be Tested
- Transverse Modes Damping
- Summary

Introduction

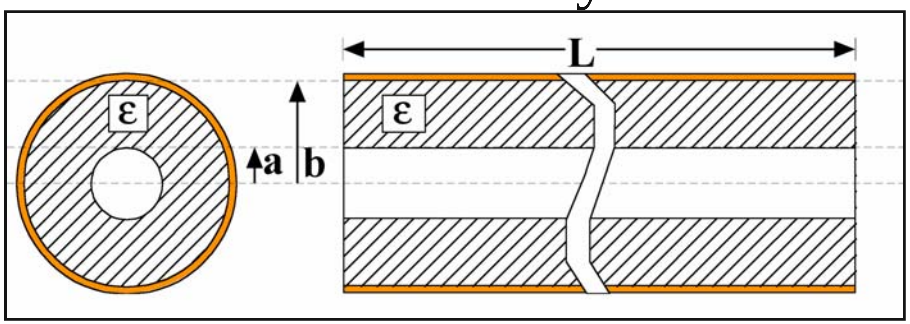
External Powered Dielectric-Loaded Accelerating (DLA) Structure

→ANL, Euclid, NRL, SLAC Collaboration

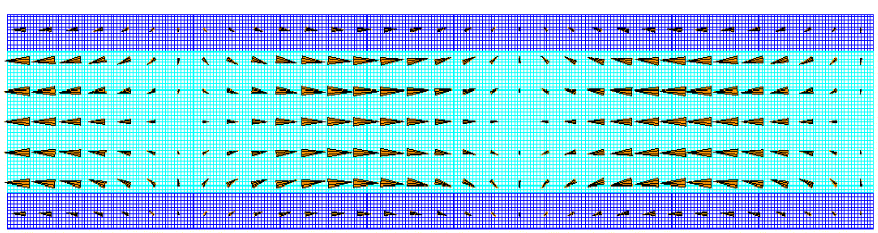
→Program Goals

- →DLA Structure Development
- →DLA Structure High Power Testing

Geometry



Electric Field Vectors



Advantages of DLA

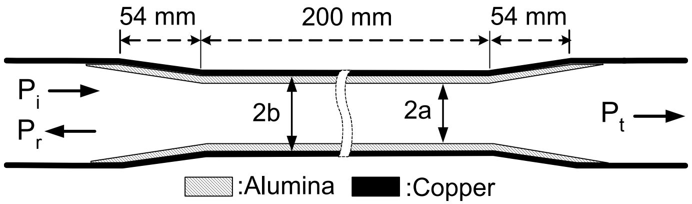
- Simple geometry
- No field enhancements on irises
- High gradient potential
- Comparable shunt impedance
- Easy to damp HOM

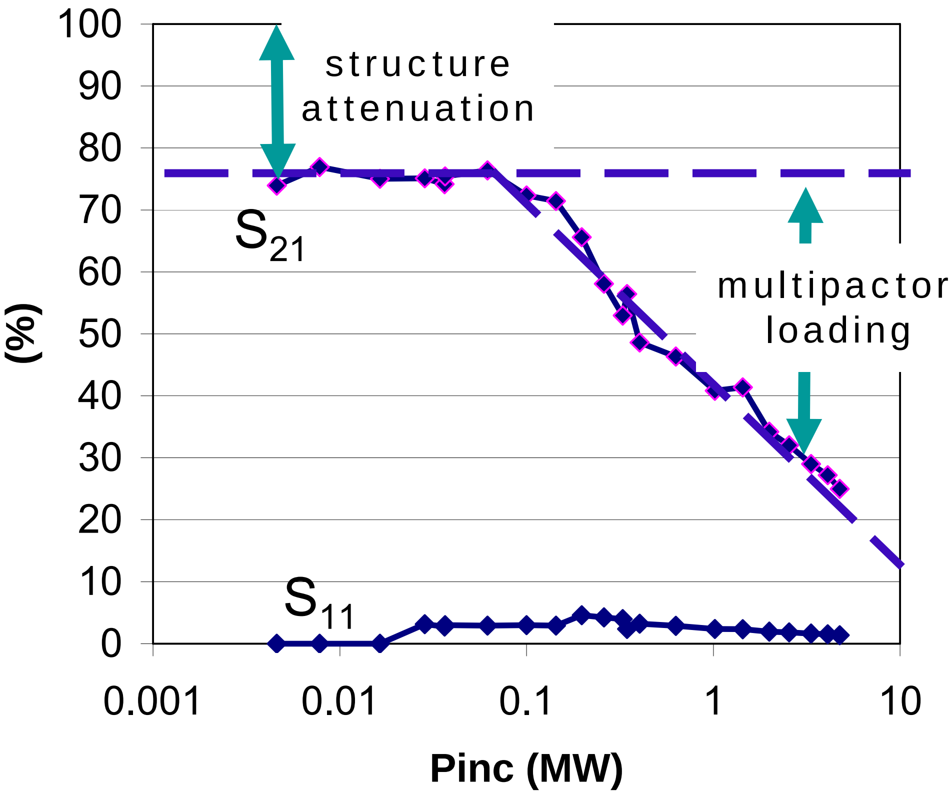
DLA Structures Tested To Date

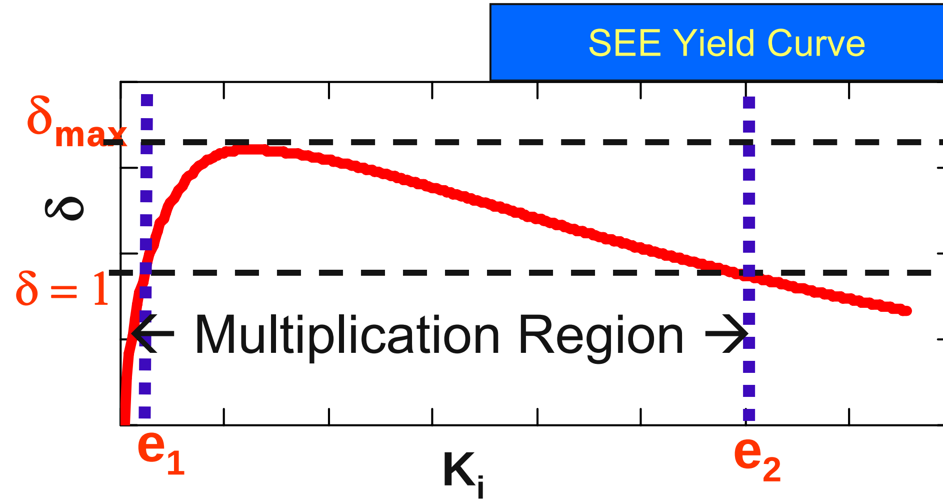
Material	Al_2O_3 †	$Mg_xCa_{1-x}TiO_3$	SiO_2
Dielectric constant	9.4	20	3.78
Loss tangent	2×10^{-4}	3×10^{-4}	2×10^{-5}
Inner radius	5 mm	3 mm	8.97 mm
Outer radius	7.19 mm	4.57 mm	12.08 mm
R/Q	6.9 kΩ/m	8.8 kΩ/m	3.6 kΩ/m
Group velocity	0.13*c*	0.057*c*	0.38*c*
RF power for 1MV/m gradient	80 kW	27 kW	439 kW
Demonstrated Gradient	8 MV/m	5.7 MV/m	9 MV/m
Principal Problem	Multipactor	Breakdown at joints	Multipactor

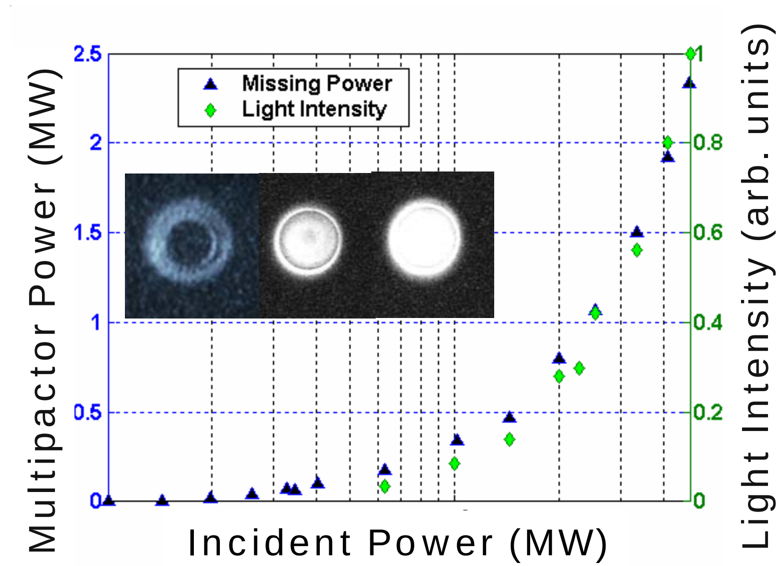
† Both non-coated and TiN coated

Multipactor

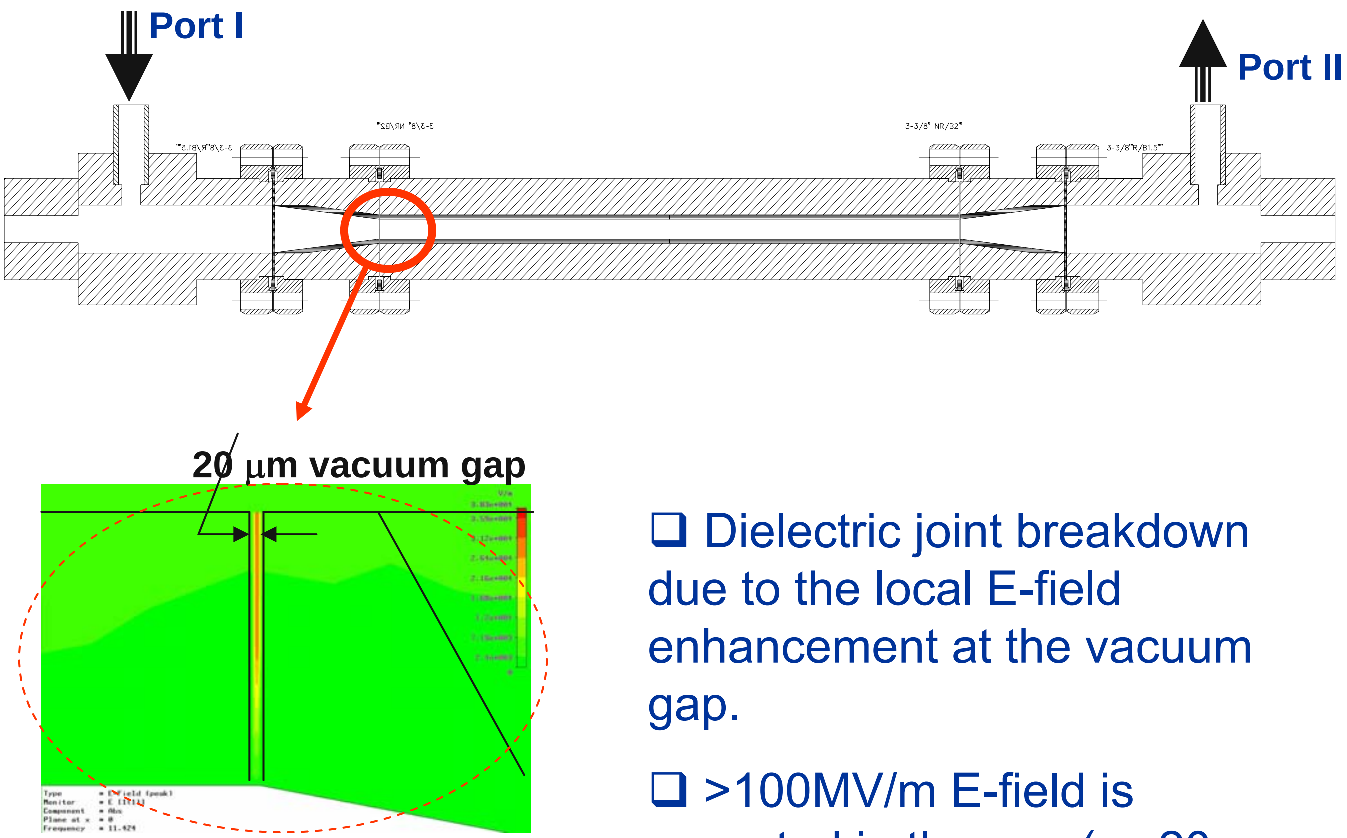




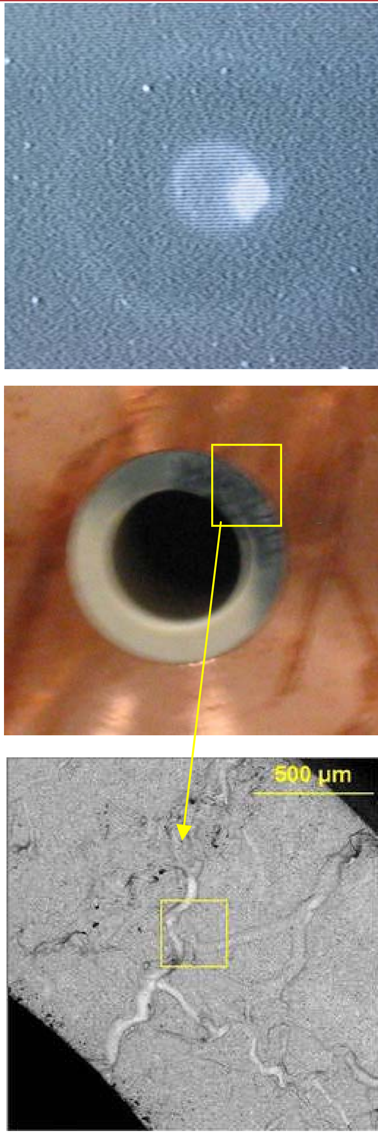




Dielectric joint breakdown



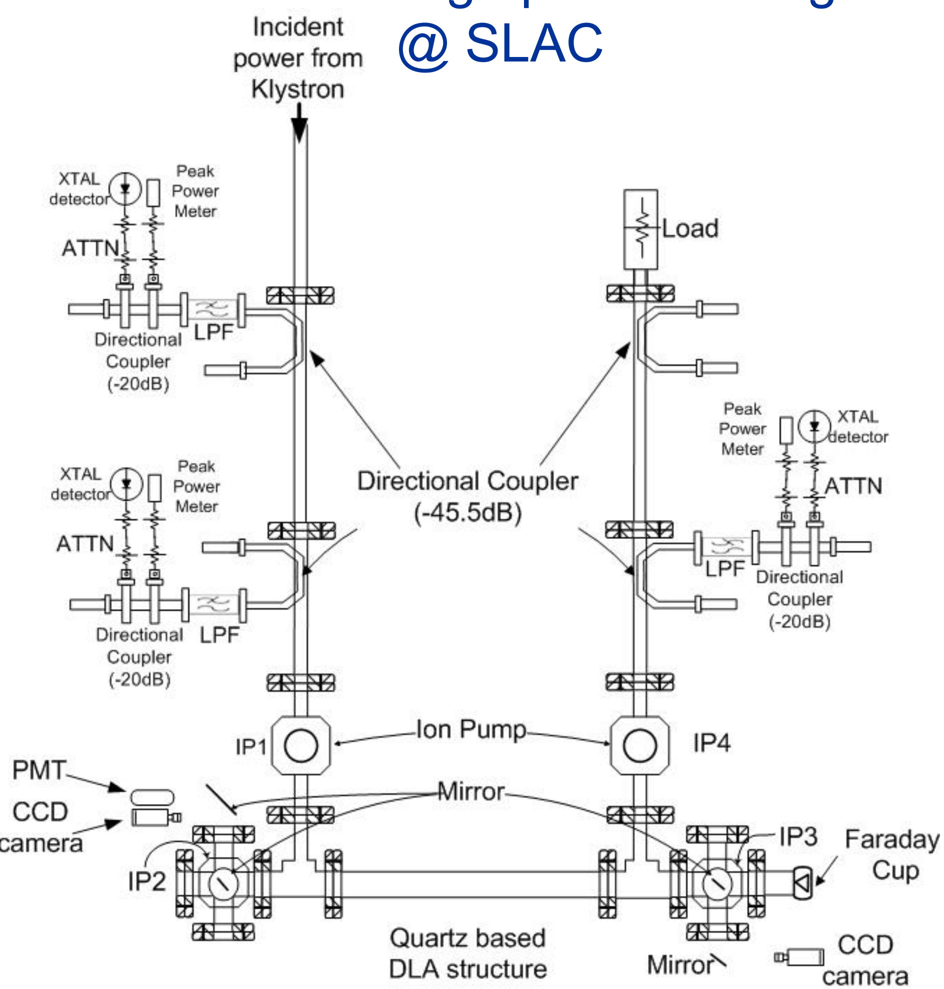
- ❑ Dielectric joint breakdown due to the local E-field enhancement at the vacuum gap.
- ❑ >100MV/m E-field is expected in the gap (ε=20, Eacc=5.7MV/m).

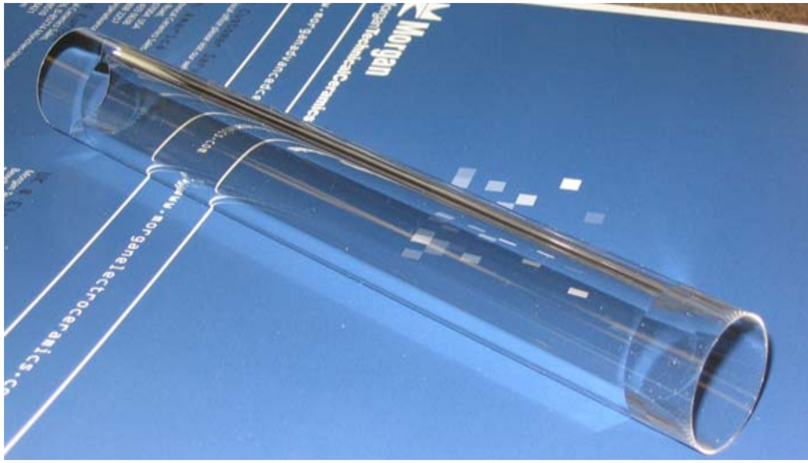


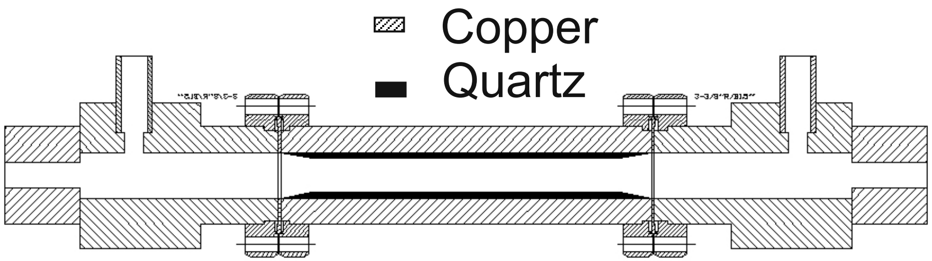
The Latest High Power Testing of Quartz Based DLA Structure @ SLAC (winter, 2006)

Quartz based DLA structure

High power testing setup
@ SLAC

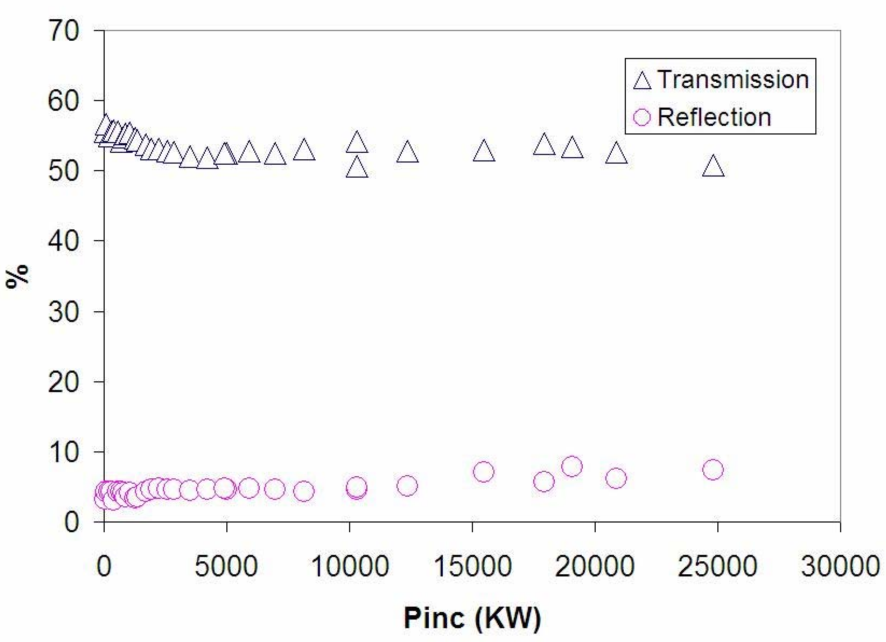


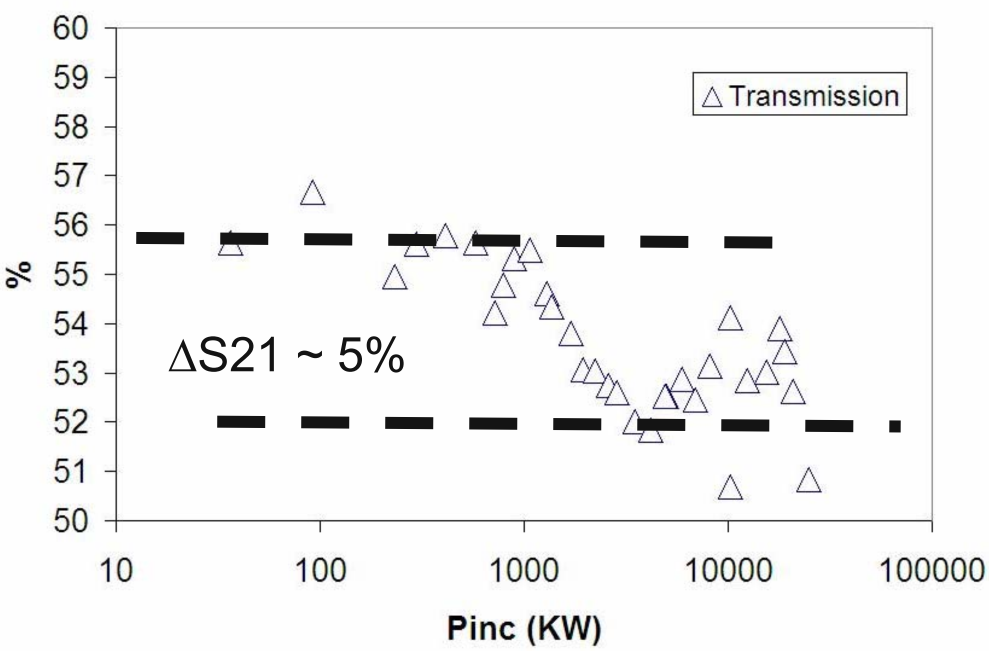




High power testing results (I)

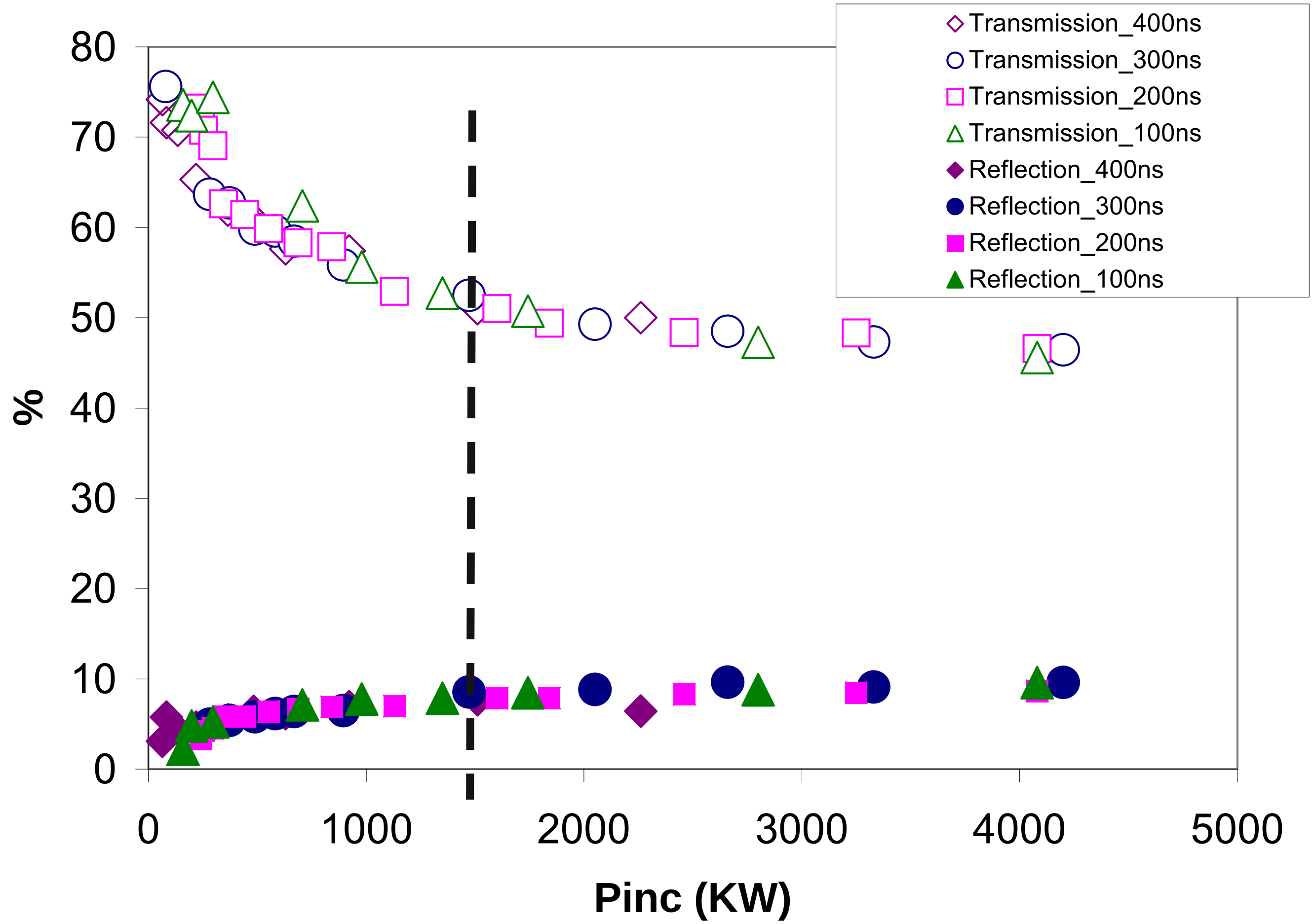
- No signature of the bulk dielectric breakdown up to 36MW, 20ns rf input, which is equivalent to 9MV/m of the initial gradient on axis.
- Multipactor was observed (with a saturation stage).





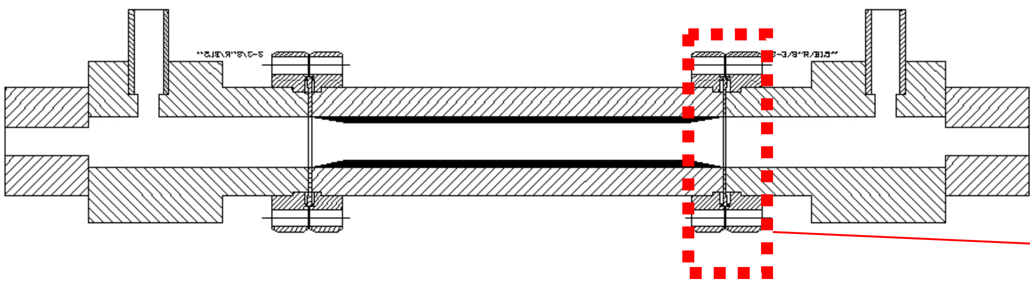
High power testing results (III)

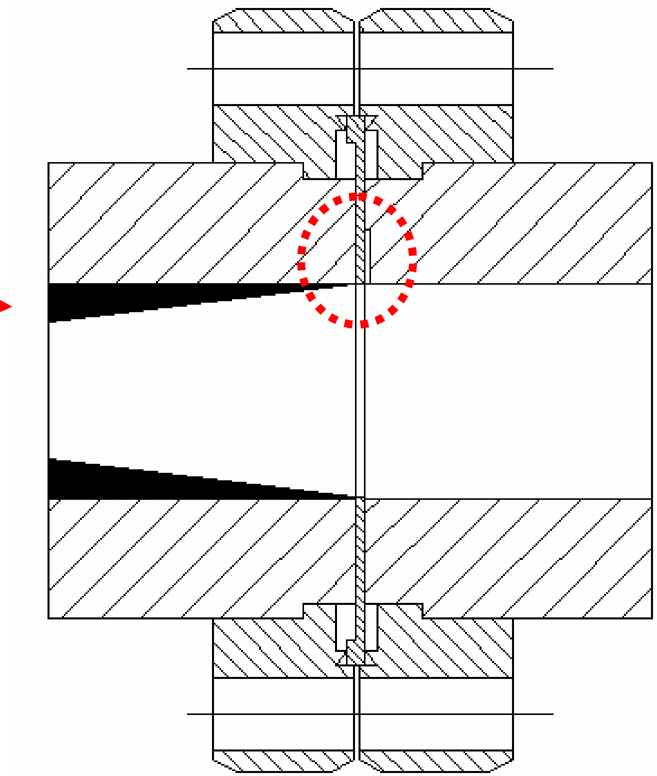
**Does Multipactor Saturation level depend on pulse length?*
→ NO



High power testing results (V)

Some breakdown signatures were observed including the signal of rf reflection and the arcing spot captured by CCD camera.
→ copper breakdown was found at the coupler gaskets while reexamining the structure after the testing.





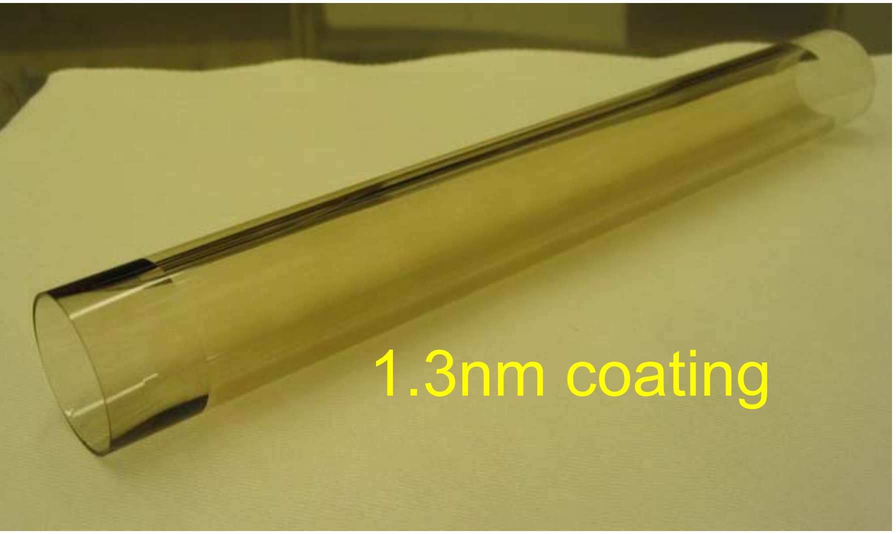
Summary of High power testing on Quartz DLA structure at SLAC

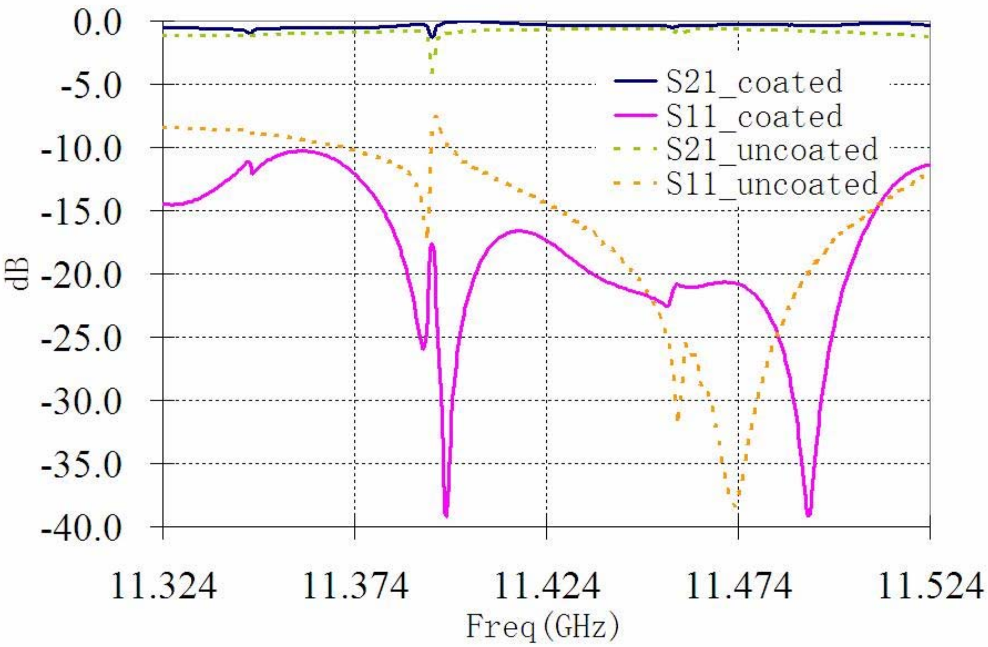
- ❑ No signature of the bulk dielectric breakdown up to 36MW (Eqv. E_{acc}=9MV/m), 20ns rf input.
- ❑ No signature of the bulk dielectric breakdown up to 25MW, 50ns rf input.
- ❑ Copper gasket breakdown was observed.
- ❑ Multipactor (with saturation stage) was observed.
- ❑ Studied the dependence of the multipactor on pulse length and repetition rate (didn't observed any obvious dependence).

What's next for multipactor study?

- TiN Coating with ALD technique (more evenly coating→ good multipactor suppressing is expected.)
- High power rf testing will be performed at NRL right after the Review

S21=-0.3dB, S11=-18dB at 11.43GHz



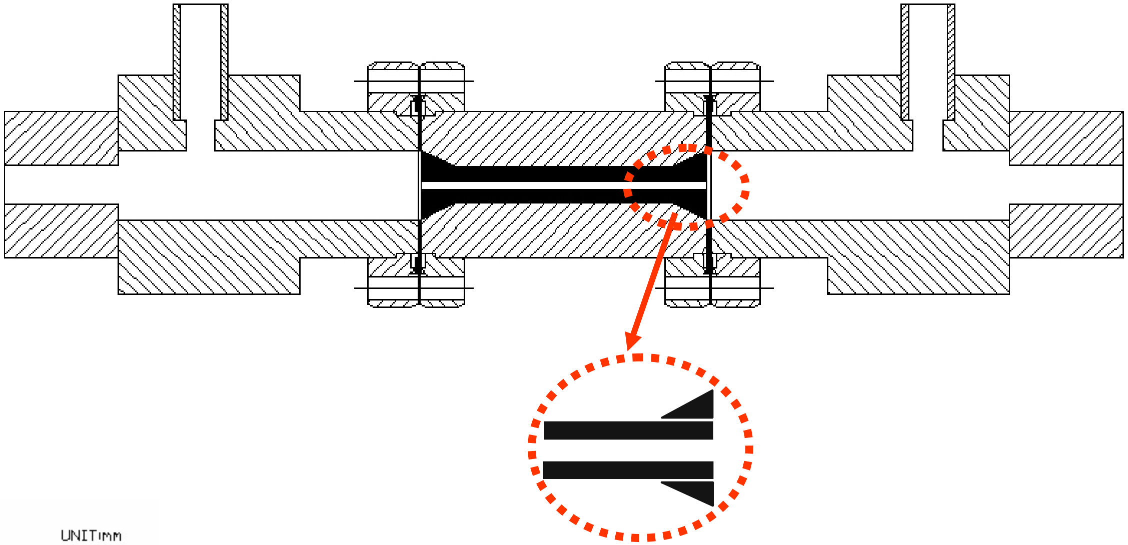


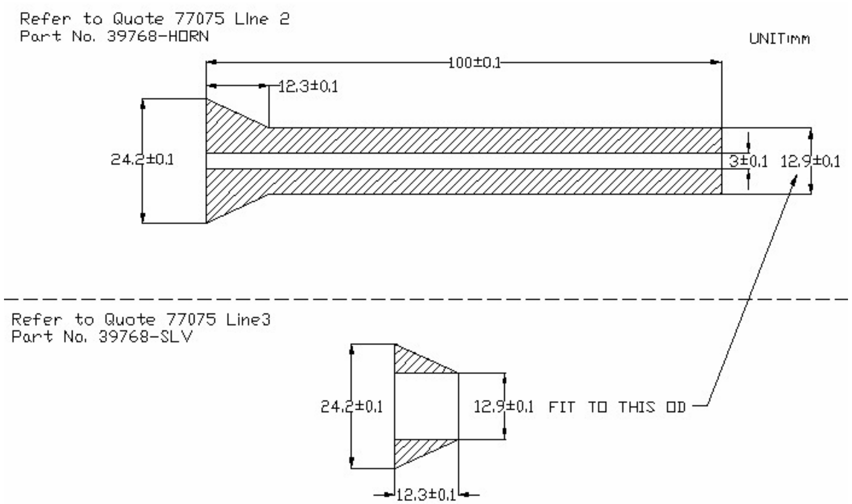
New Designs

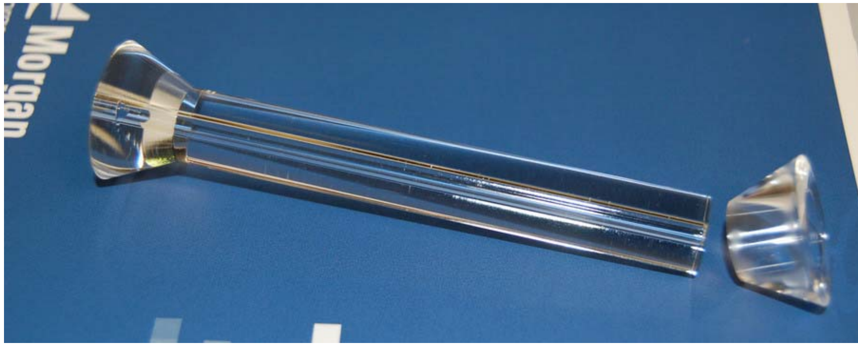
New Design (axial gap free structure)

Mode converter coupling scheme:

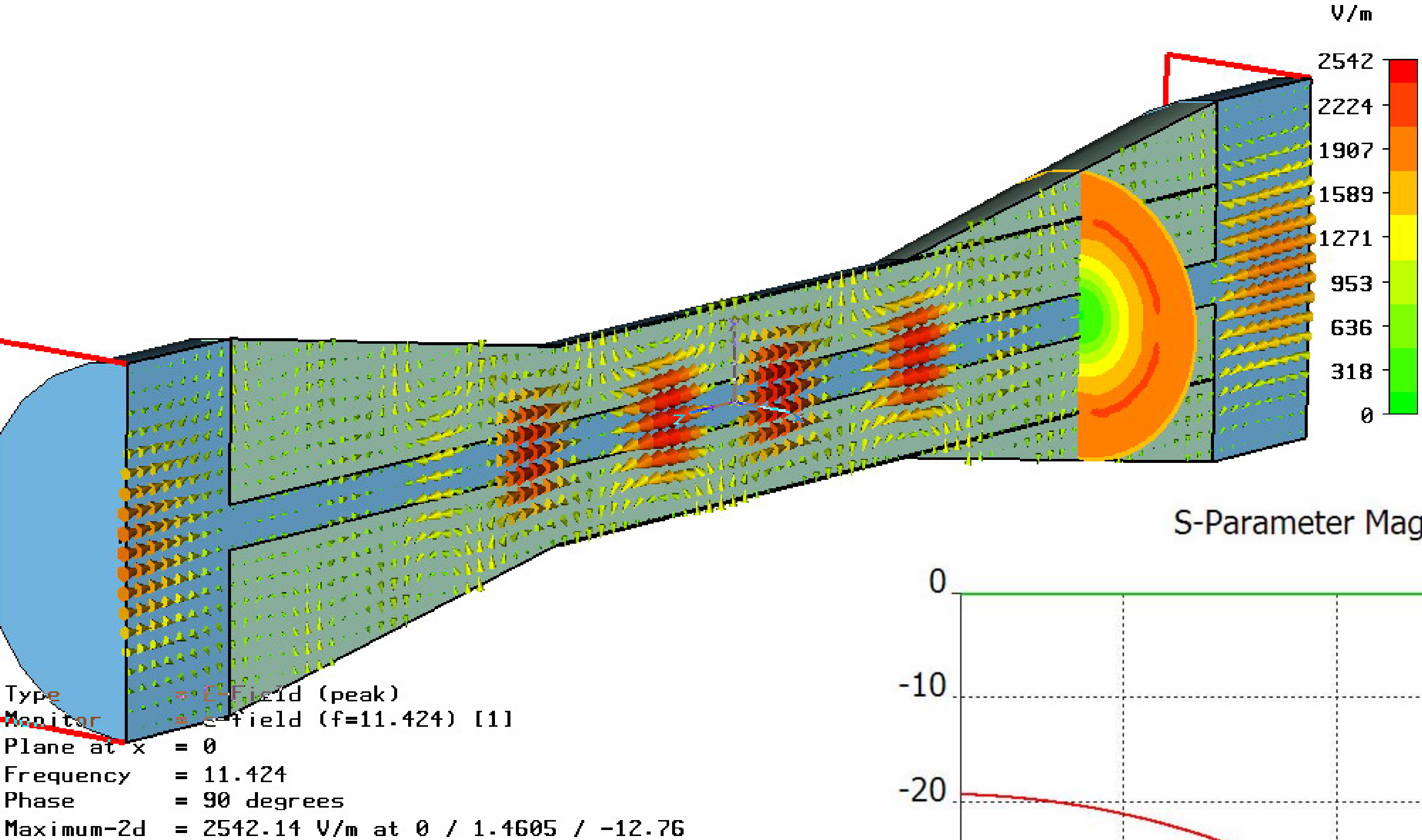
- *No longitudinal dielectric gap*
- *Reused coupler*
- *No separate matching section*
- *Easy to change dimensions and material of loaded dielectrics*

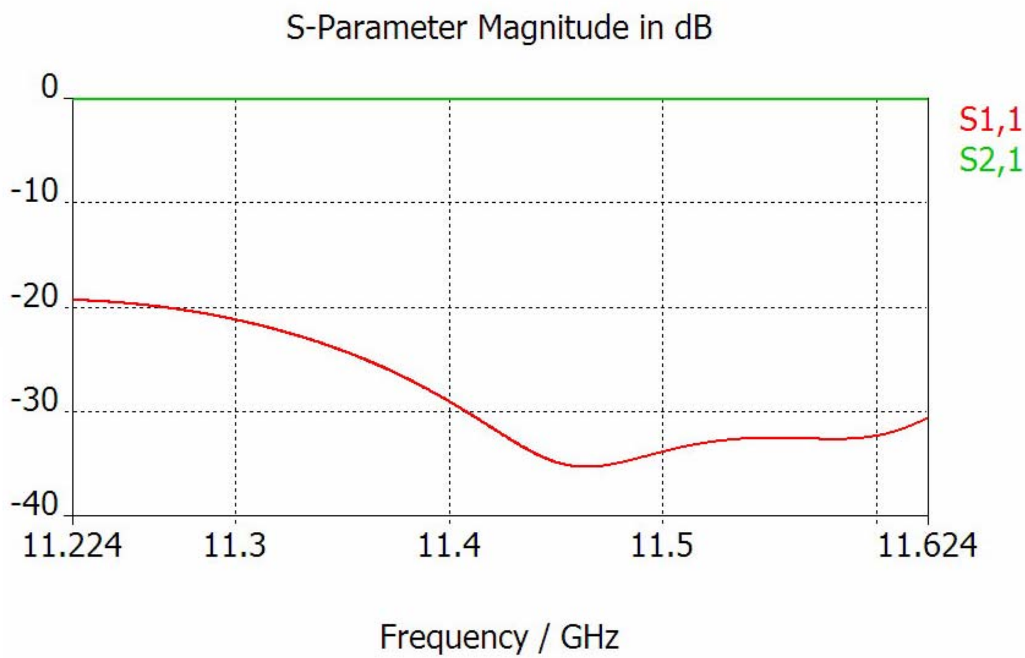






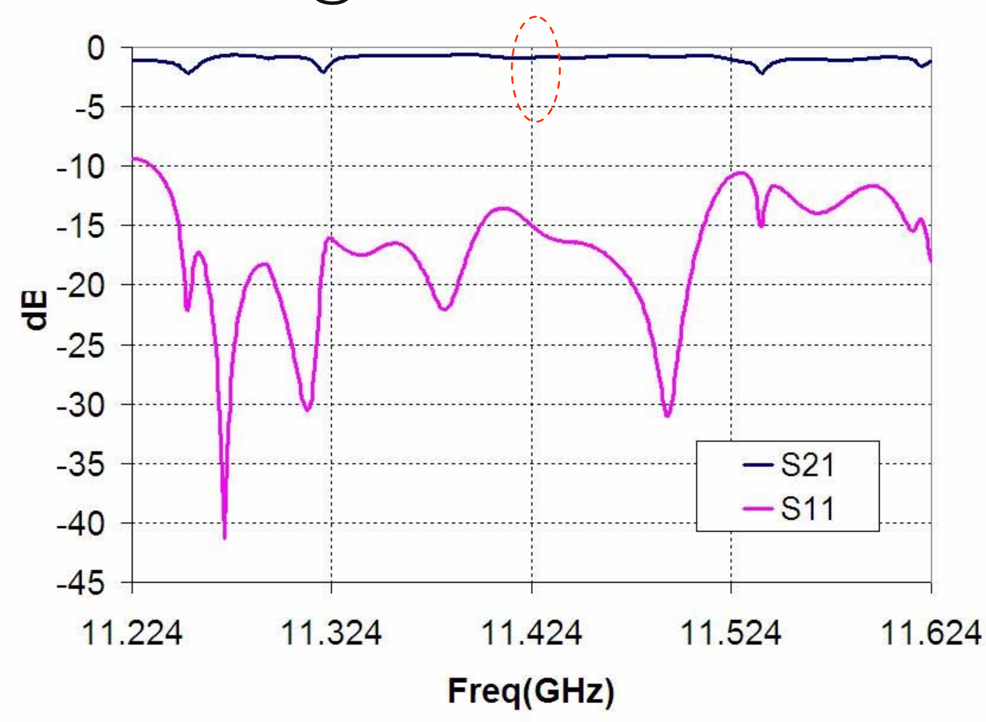
New Design (axial gap free structure)





New Design (axial gap free structure)

S21=-0.8dB; S11=-15dB
@11.424GHz

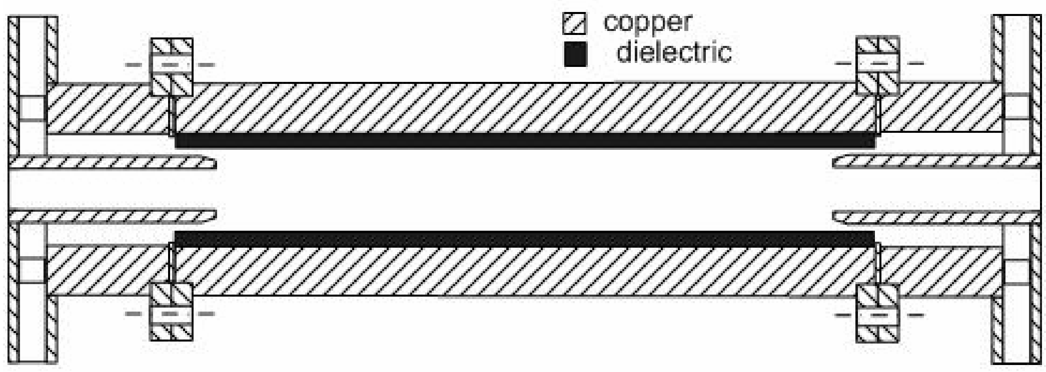


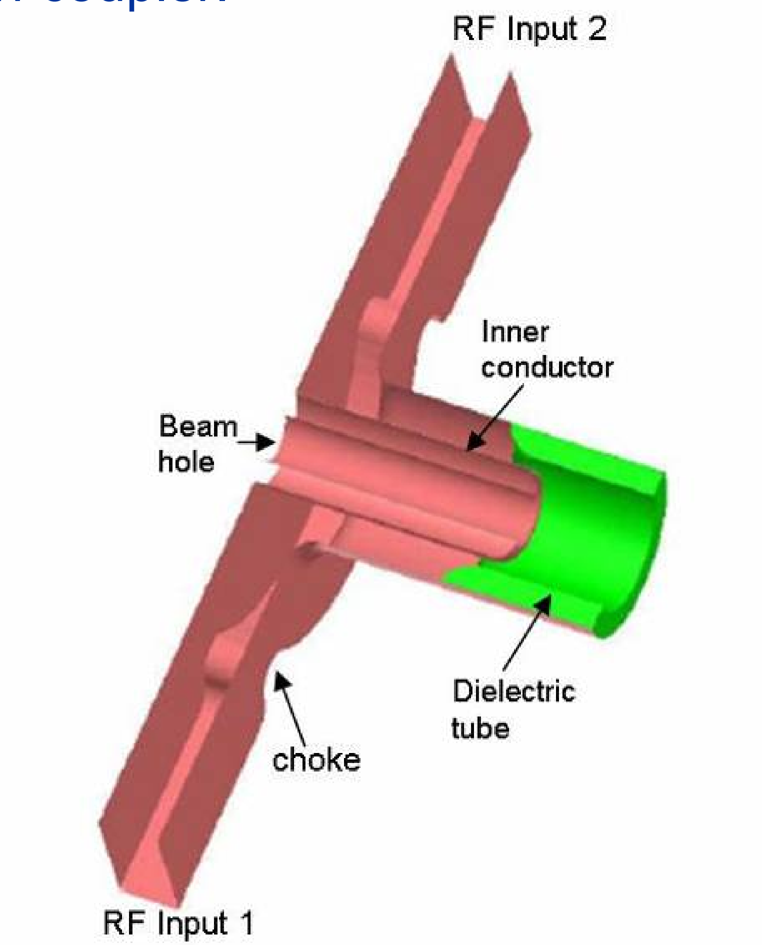
New Design (gapless structure)

Gapless DLA structure based on coaxial type rf coupler.

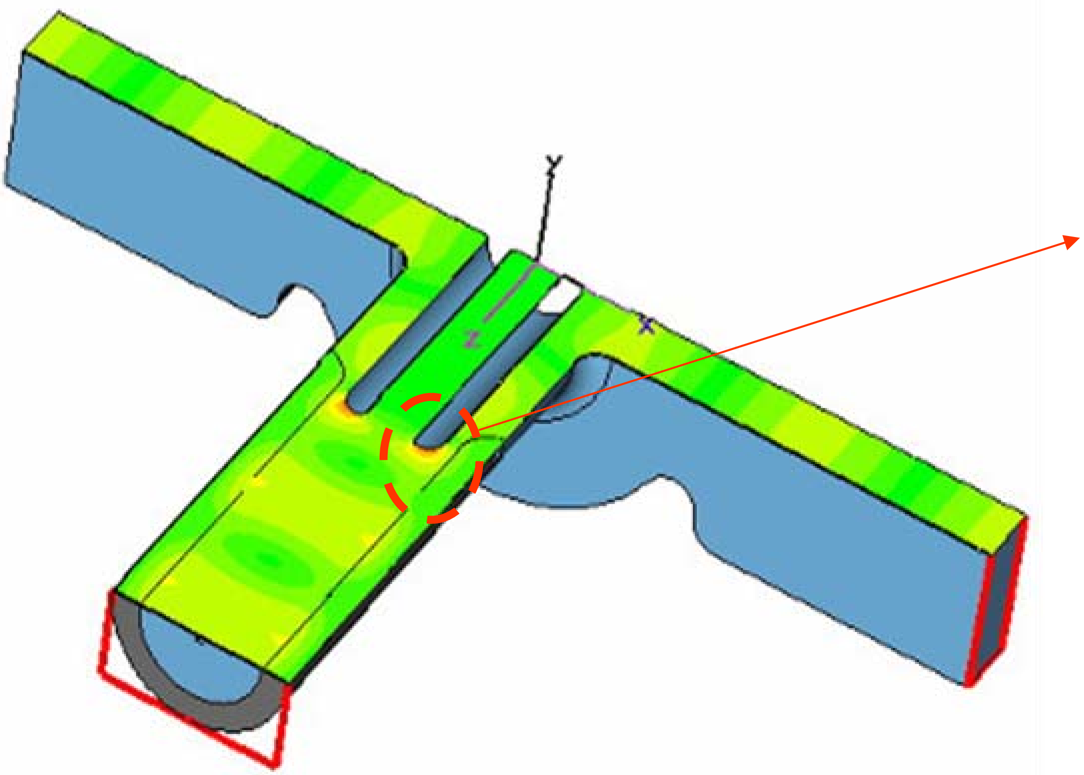
Coaxial type rf coupling scheme:

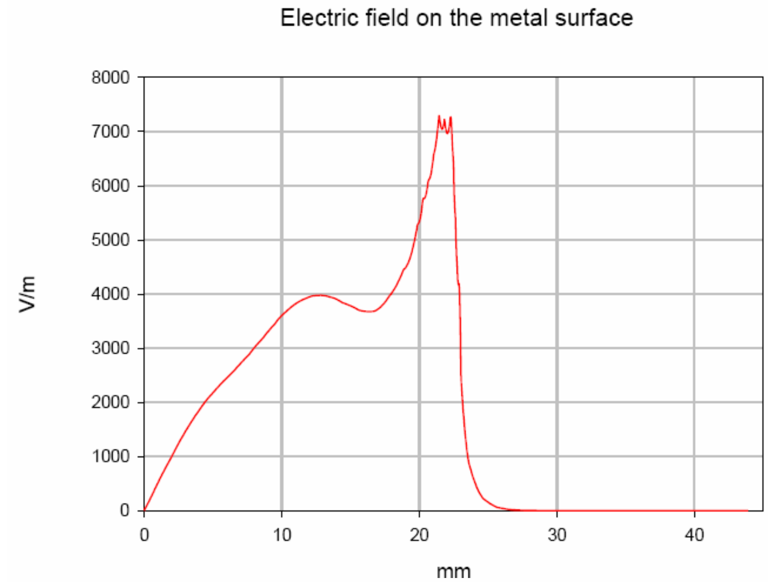
- *No taper matching section*
- *No gaps*
- *Shorter rf coupling section*
- *Better hybrid mode suppression*

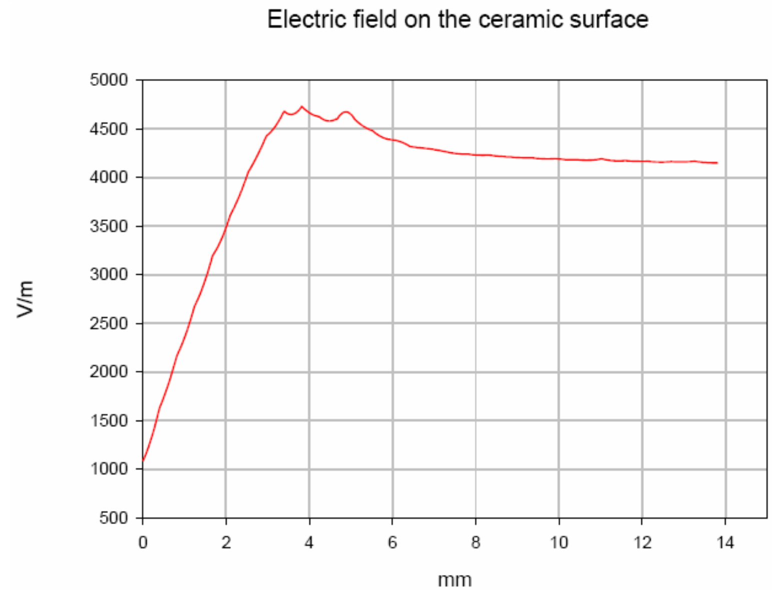




New Design (gapless structure)



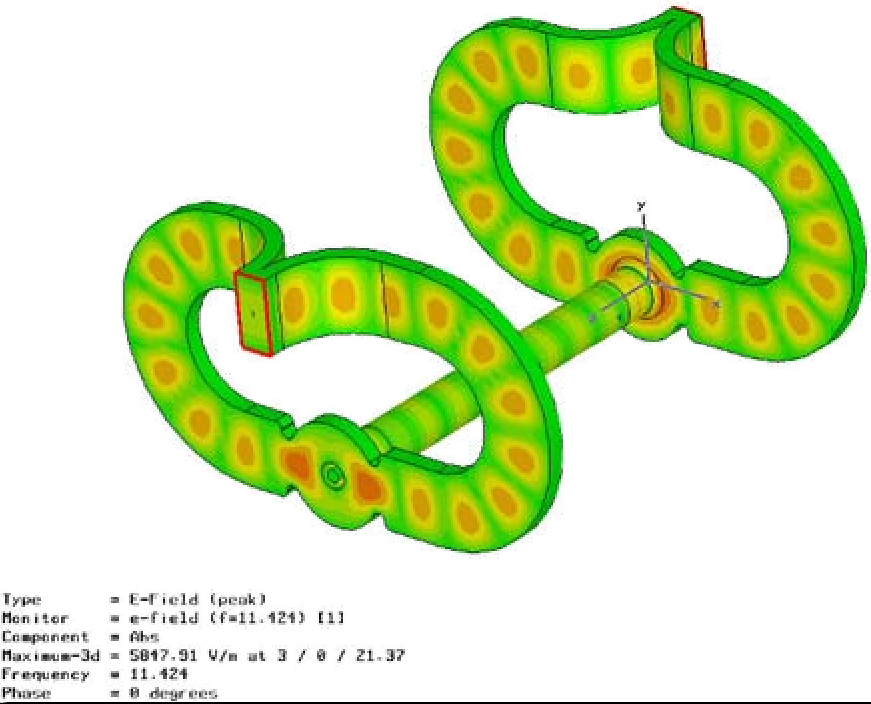


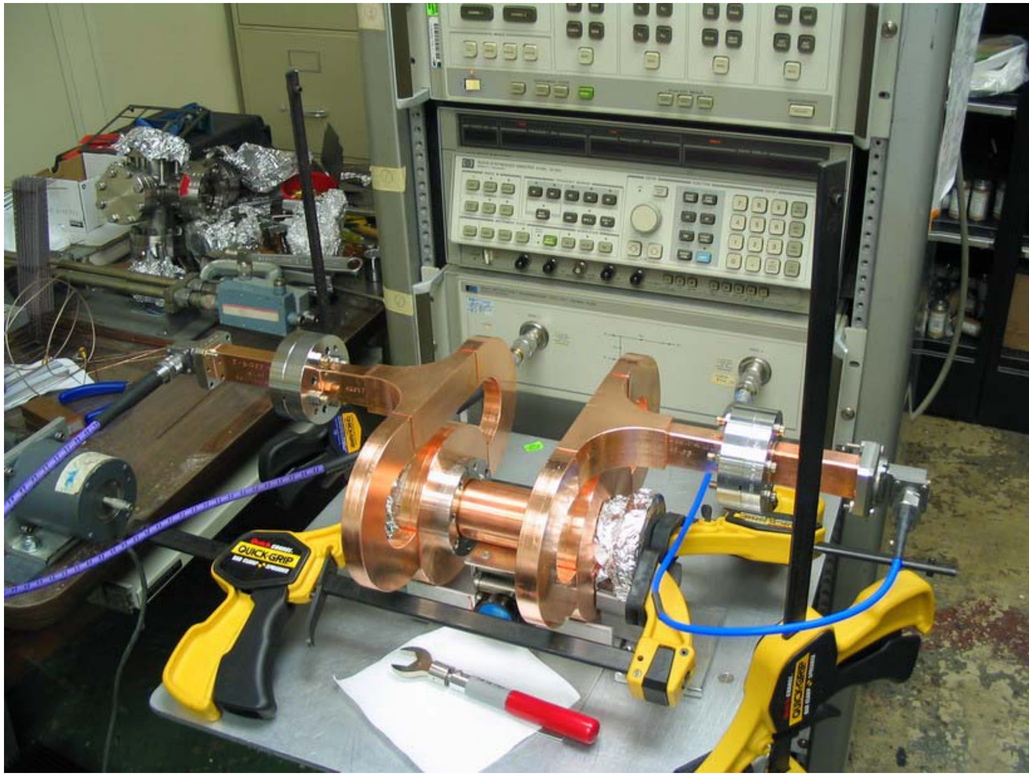


The highest electric field in the new coupler appears at the inner conductor tip. For 20 MW rf input, the electric field at the tip will reach 24 MV/m, much less than the copper breakdown voltage threshold.

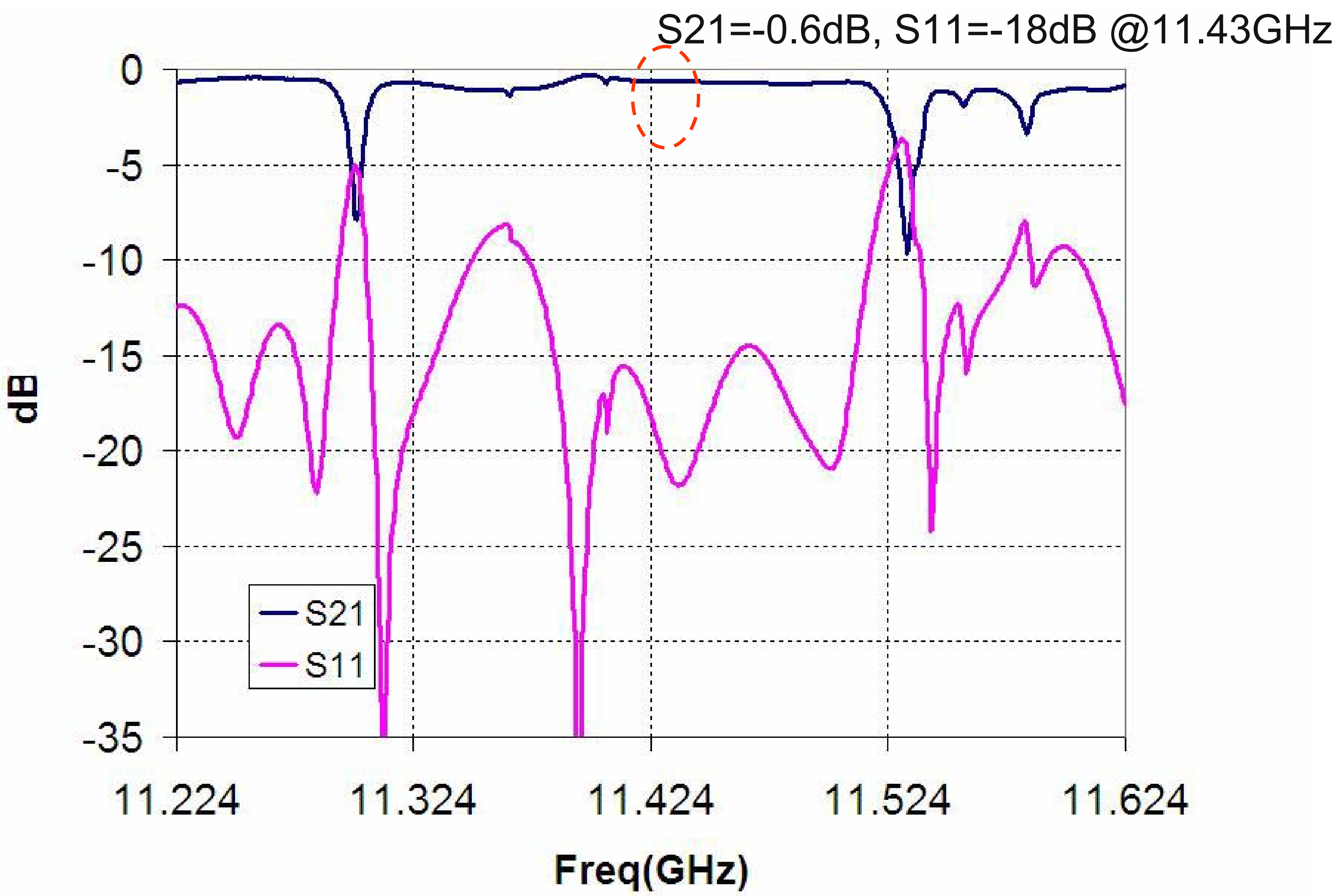
New Design (gapless structure)

- *Alumina based gapless DLA has been fabricated.*
- *Bench measurements have been done; a high power test has been scheduled at NRL.*
- *MCT-20 based gapless DLA structure has been simulated.*

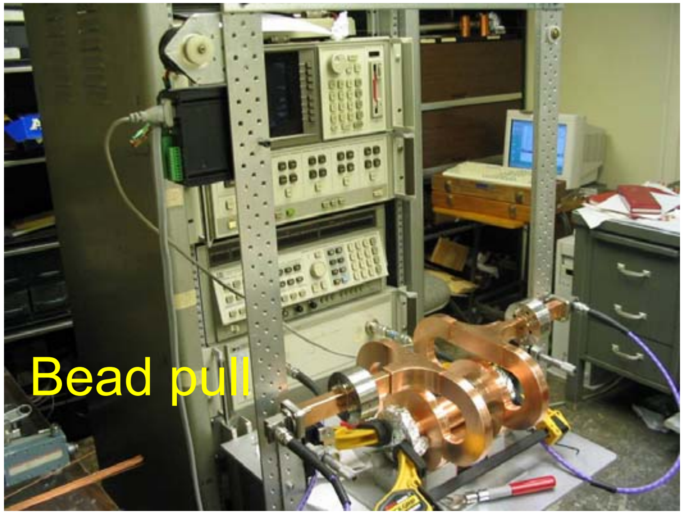


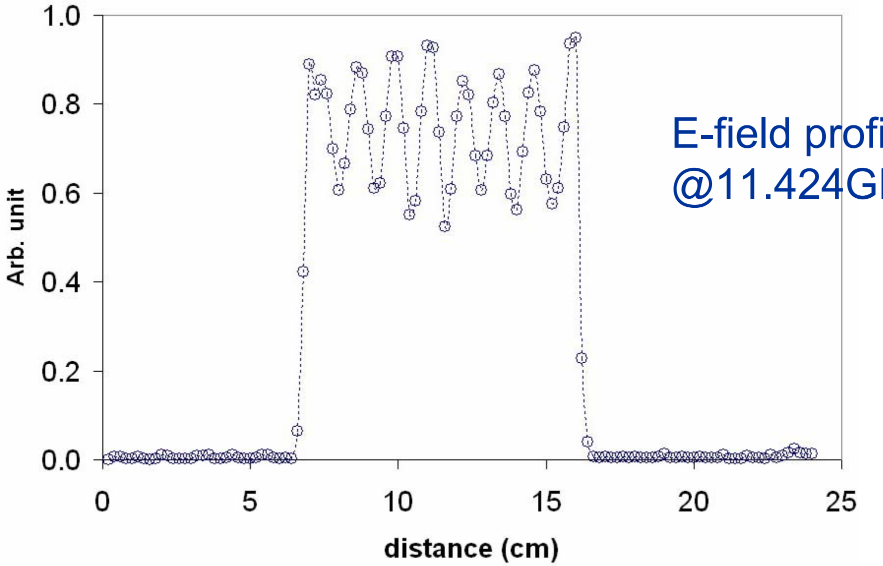


New Design (gapless structure)



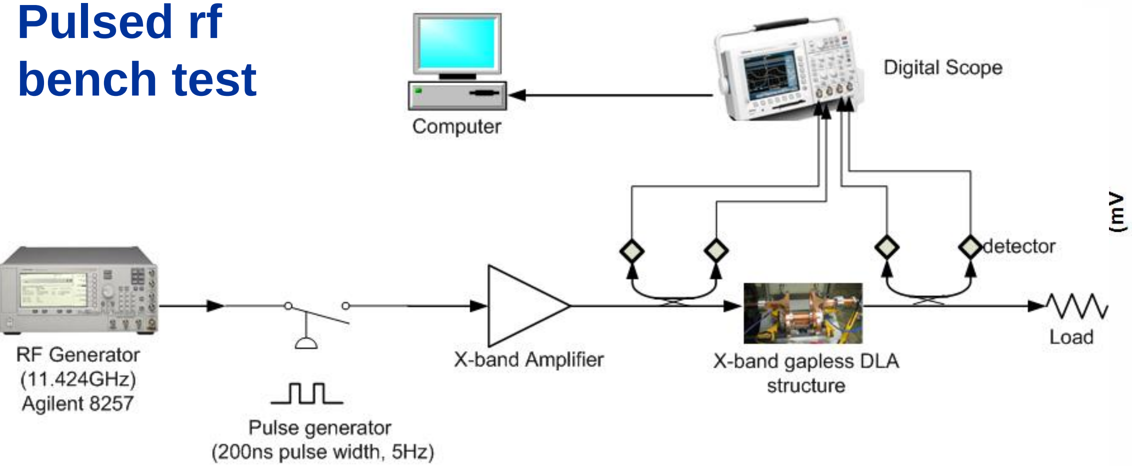
New Design (gapless structure)

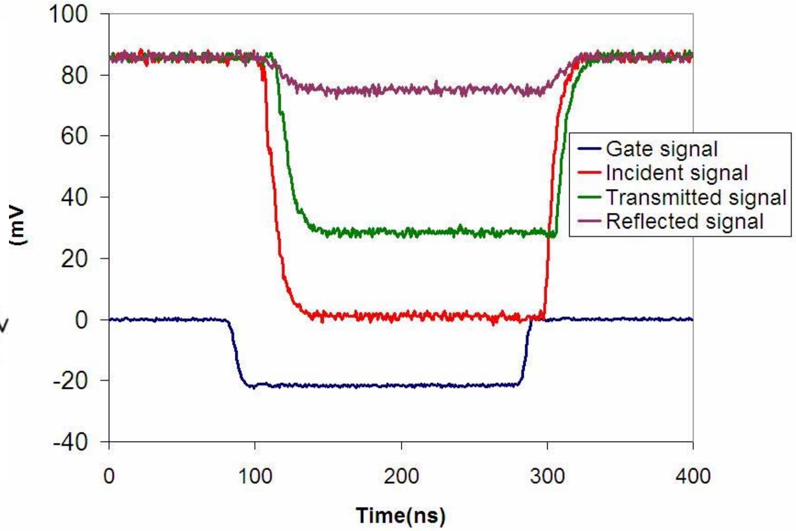




E-field profile @11.424GHz

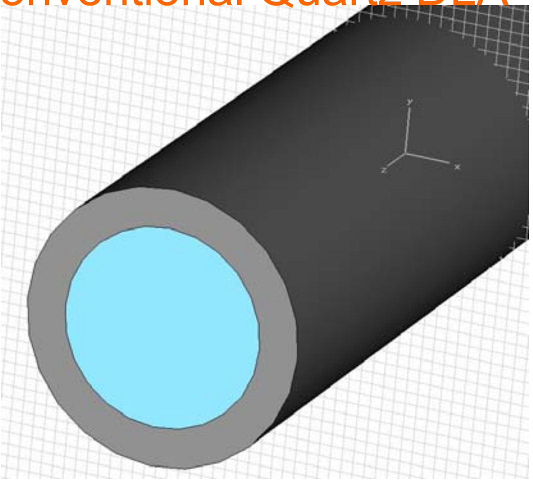
Pulsed rf bench test

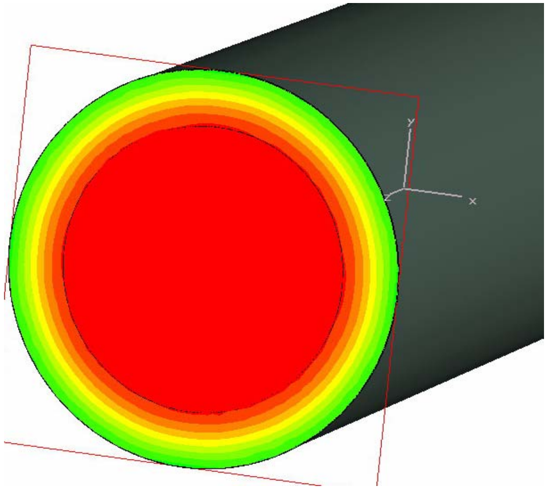




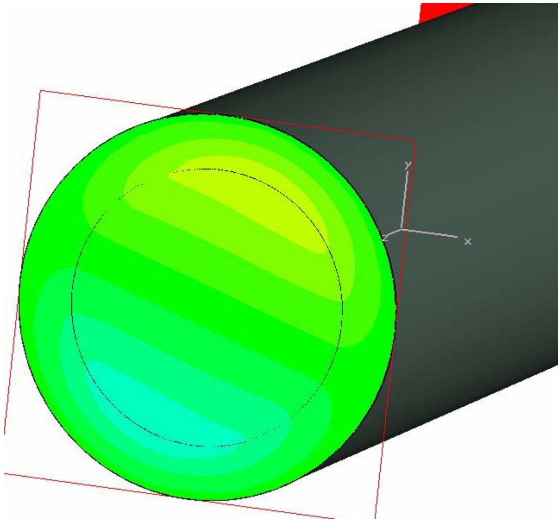
New Design (hybrid mode damping structure)

Conventional Quartz DLA

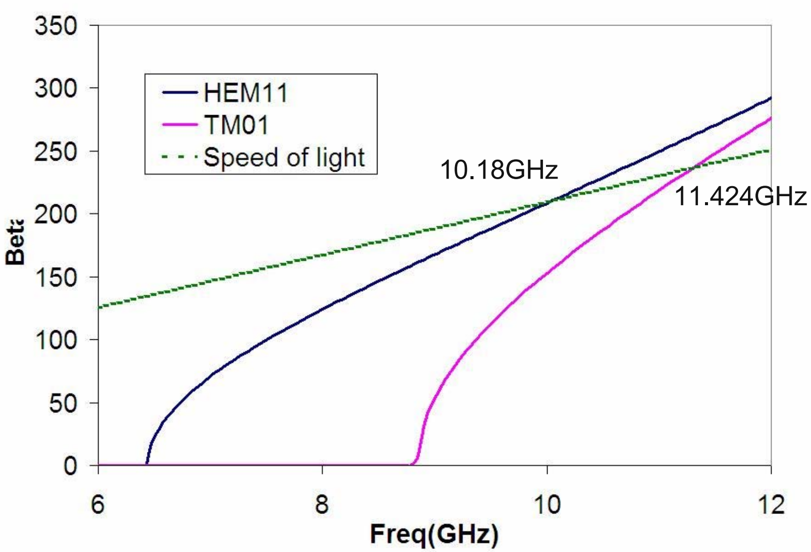




TM01 mode Ez

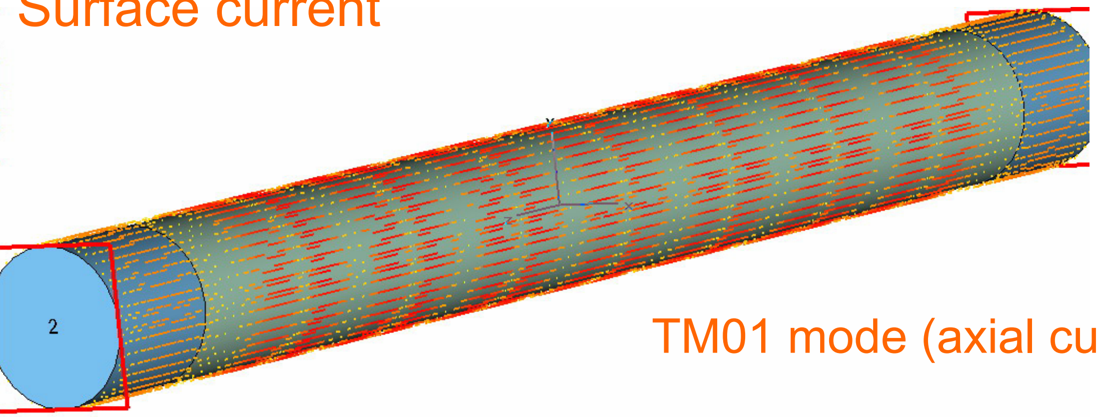


HEM11 mode Ez



New Design (hybrid mode damping structure)

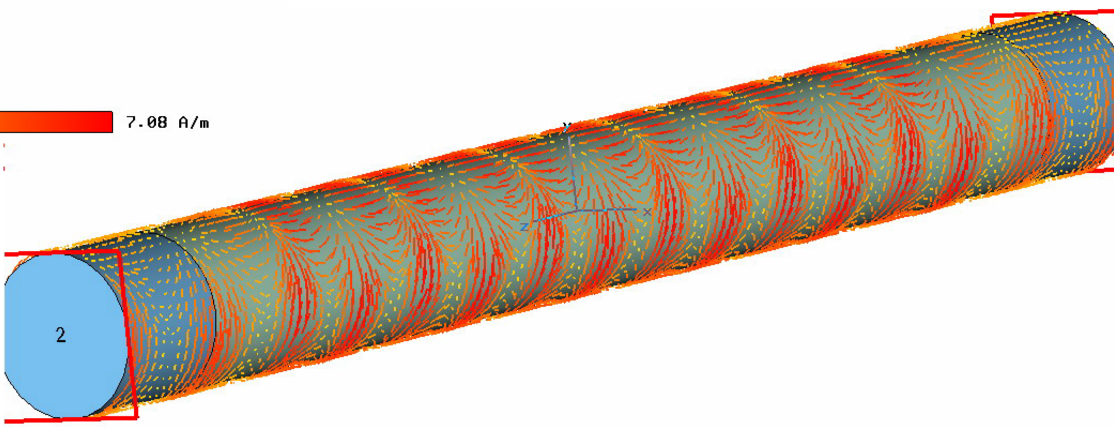
Surface current



TM01 mode (axial current only)

Type = Surface Current (peak)
Monitor = h-field (f=11.424) [1(3)]
Frequency = 11.424
Phase = 0 degrees

0 7.08 A/m



HEM11 mode (azimuthal current included)

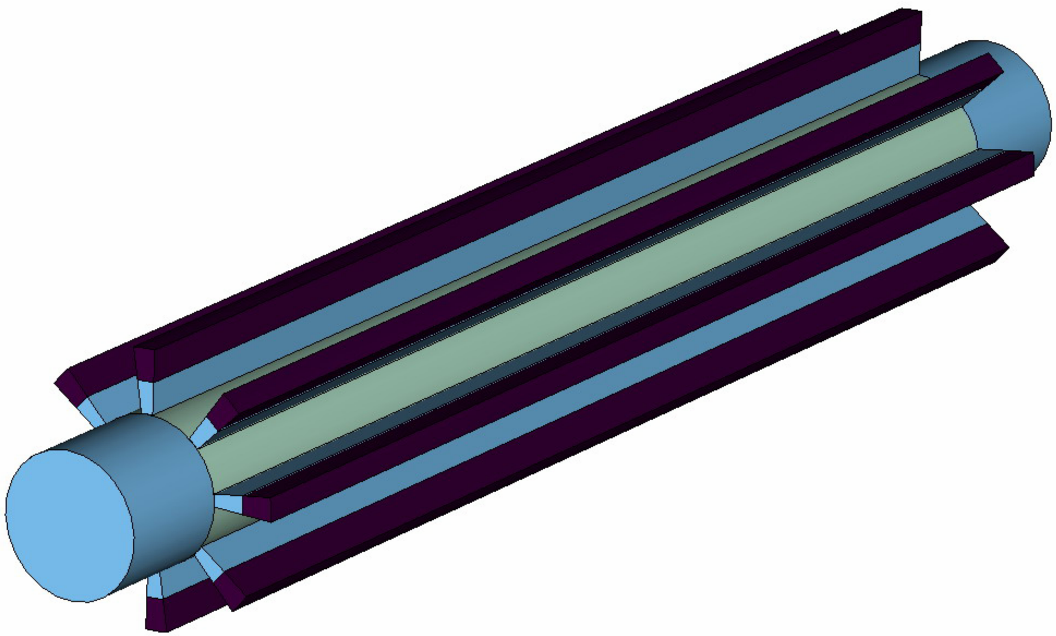
Type = Surface Current (peak)
Monitor = h-field (f=10.18) [1(1)]
Frequency = 10.18
Phase = 0 degrees

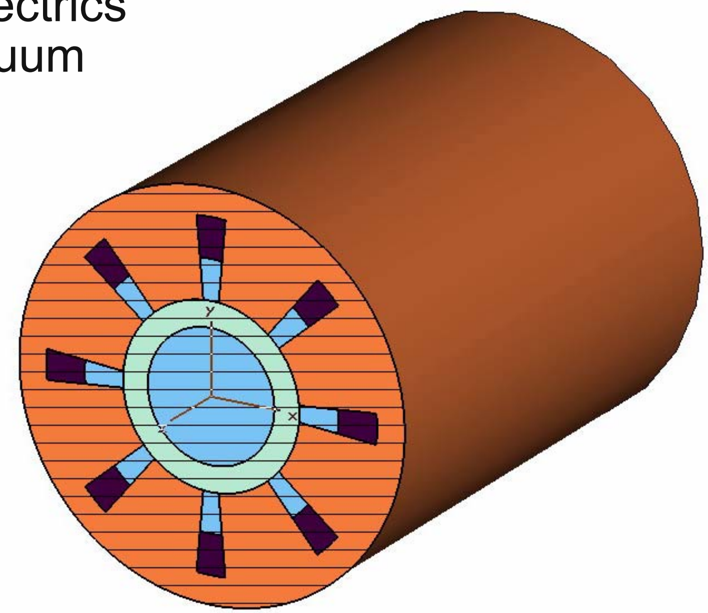
0 5.06 A/m

New Design (hybrid mode damping structure)

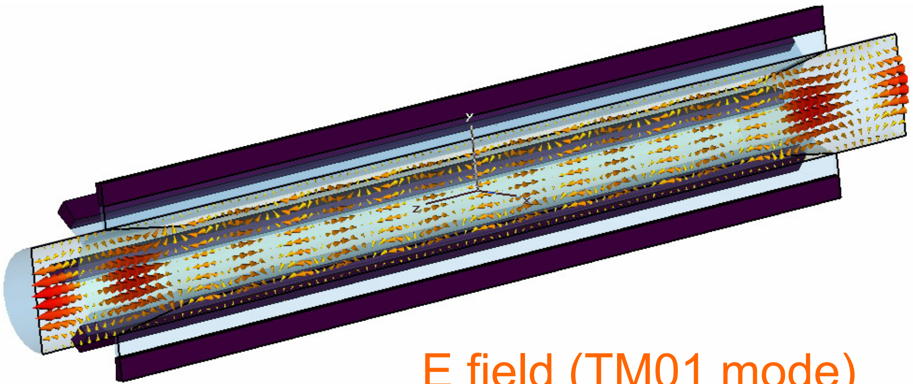
Hybrid mode damping DLA

SiC(ε_r ~13; tanδ ~0.22 @ 11GHz)
Copper
Dielectrics
Vacuum





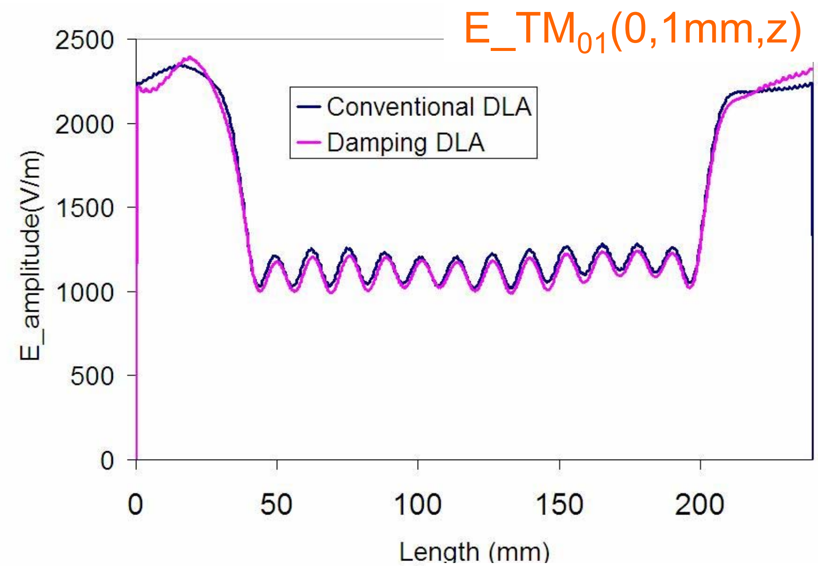
New Design (hybrid mode damping structure)

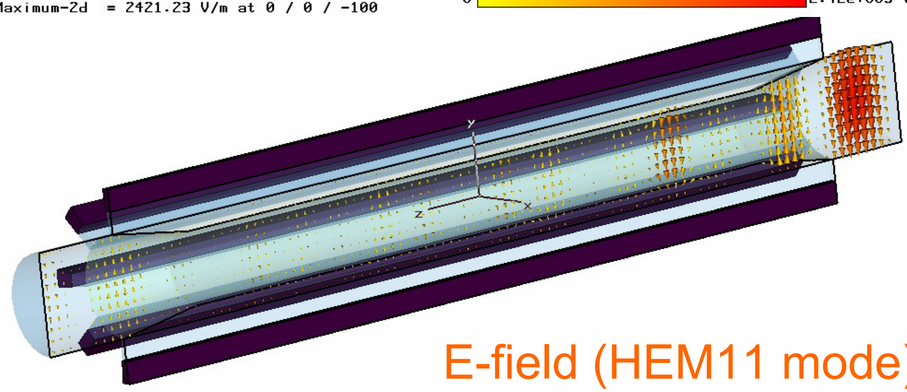


E field (TM01 mode)

```
Type          = E-Field (peak)
Monitor       = e-field (f=11.424) [1(3)]
Plane at x    = 0
Frequency     = 11.424
Phase         = 0 degrees
Maximum-2d    = 2421.23 V/m at 0 / 0 / -100
```

0 — 2.42e+003 V/m

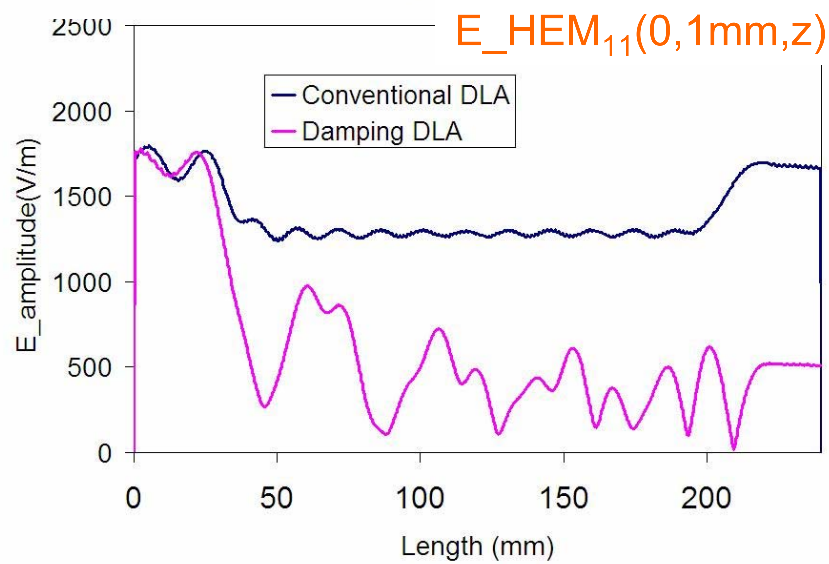




E-field (HEM11 mode)

```
Type          = E-Field (peak)
Monitor       = e-field (f=10.18) [1(1)]
Plane at x    = 0
Frequency     = 10.18
Phase         = 0 degrees
Maximum-2d    = 1786.45 V/m at 0 / -0.997062 / -117.576
```

0 — 1.79e+003 V/m



New Design (hybrid mode damping structure)

X-band DLA structures	Accelerating Mode (TM01 mode)			Parasitic Mode (HEM11 mode)		
	Freq (GHz)	Q (conventional DLA)	Q (damping DLA)	Freq (GHz)	Q (conventional DLA)	Q (damping DLA)
Quartz based (ε_r =3.8; ID=17.9mm; OD=24.16mm)	11.424	9825*	7812*	10.18	10877*	49*
MCT-20 based (ε_r =20; ID=6mm; OD=9.13mm)	11.424	2864*	2440*	9.915	2546*	100*

*SiC (ε_r ~13; tanδ ~0.22 @ 11GHz) used in the calculation of the damping DLA structures; dielectric losses of the loaded materials are not included in the Q calculation; Slots / circumference = 22%.

Summary

- Investigating characteristics of multipactor.
- Studying multipactor suppressing technique.
- Understood the mechanism of the dielectric joint breakdown.
- Developed an axial gap free DLA structure and a gapless DLA structure, and bench tested.
- Designed hybrid mode damping DLA structure.
- More High power rf tests are planned.